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Comparative Altitudinal Gradient Aspect on Natural Regeneration of *Quercus leucotrichophora* A. Camus in Renuka Ji Forest Division, Himachal Pradesh, India

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ABSTRACT

Quercus leucotrichophora forests are a repository for biological diversity, carbon, nutrient reserves, and multipurpose Himalayan tree species and crucial for sustaining rural livelihoods, controlling ecosystem services. As a result, their protection and sustainable usage in the future are essential to reduce the effects of climate change, as well as the biological and environmental stability of sensitive ecosystems in North-western Himalayan ecosystem. Hence the present investigation was carried out to document the natural regeneration status of *Quercus leucotrichophora* across different altitudinal gradients i.e., A_1 (1200-1500 m), A_2 (1500-1800 m) and A_3 (1800-2100 m) above mean sea level (amsl) in Himachal Pradesh Forest ranges. Statistical procedures were used for collection of data, analyzation, and interpretation. The present study reveals that the decreasing trend of natural regeneration of *Quercus leucotrichophora* with altitude: $A_1 > A_2 > A_3$ were recorded maximum at lower altitudinal gradient (1200-1500 m) (A_1) and minimum at higher altitudinal gradient (1800-2100 m) (A_3).

Keywords Altitudinal gradient, Ban oak, Regeneration, Himalayan forest, Ecosystem services.

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INTRODUCTION

Forests are defined as tree-dominated terrestrial ecosystems with a tree canopy covering at least 10 % of the ground area. The relevance of forests in ecology cannot be overstated, and their diversity must be outlined in order to depict ecosystems, the functional attributes of which are enhanced by the existence of distinct edaphic, topographic, and meteorological components. The global loss of biodiversity is a result of indiscriminate human resource use (Savard *et al.* 2000). Forests are a significant resource premise in the Himalayas, the world's wealthiest and youngest mountain range, which covers more than one-fifth (18%) of India's geographical area. Despite their diverse floral composition, these forests are dominated by a few widely spread plant genera, the most well-known of which is the Quercus species, also known as oak. Oaks (Quercus spp.) are the most prevalent

Fig. 1. *Quercus leucotrichophora* (Ban Oak Tree species).

and dominant tree species in the Indian Himalayan moist temperate forests.

Quercus leucotrichophora, also known as banjh oak, ban oak, and banj oak, belongs to the Fagaceae family (Fig 1). Ban Oak is a multipurpose Himalayan tree species, ban oak dominated forests has greater potential to store soil organic carbon stock than compared to other forests which play key role in combating climate change (Murari *et al.* 2023) and crucial for sustaining rural livelihoods, controlling ecosystem services (mainly recharge of springs), and preserving biodiversity in the North-western Himalayan area. Unhindered urbanisation, construction activities, and an ever-increasing human population have put enormous strain on forests, leading them to decline at an alarming rate. In recent decades, forest species regeneration patterns have played an essential role in minimising future climatic consequences. Forest crop regeneration is a prerequisite for the practise of scientific forestry since failure or underperformance would jeopardise the sustainability of forest production. Natural regeneration evaluation is a crucial aspect that impacts not only production and management mechanisms in forest species (Greene *et al.* 1999), but also whether there is satisfactory or woefully inadequate regeneration in the forest (Hanssen 2003).

To ensure the preservation of forest community composition and ecological consistency; effective seedling, sapling, and young tree management is essential (Moravie *et al.* 1997). Many plant communities and their succession patterns may be influenced by human disturbances such as selective logging, timber extraction, grazing, fire, and land clearance for permanent agriculture (Hong *et al.* 1995, Fujisaka *et al.* 1998). The regeneration status potential of a species in a community is analyzed for the population dynamics of seedlings and saplings in a forest community. It has also been witnessed that oaks in accessible government forests have been maimed by prolonged lopping, causing them to die out quickly. Few patches of intact oak forests persist in the region today, and those that do remain are changing rapidly due to incursion by alien invasive species such as *Eupatorium adenophorum, Lantana camara,* and more assertive species such as chir pine (*Pinus roxburghii*). The replacement of oak by pine is indeed a common and expanding rapidly phenomenon.

MATERIALS AND METHODS

The present investigation was carried out during the year 2021-2022 in Renuka Ji Forest Division under three forest ranges namely Shillai Forest Range, Nohra Forest Range and Sangrah Forest Range in Indian State of Himachal Pradesh with three altitudinal gradients i.e., A_1 (1200-1500 m), A_2 (1500-1800 m) and A_3 (1800-2100 m) above mean sea level (amsl) (Fig. 2). The observations were recorded for

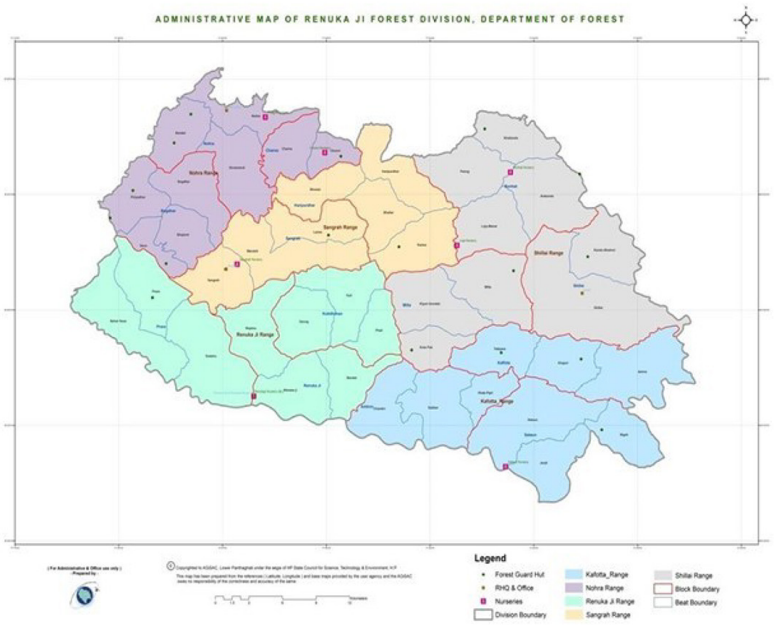

Fig. 2. Map location of study area (Source – Working Plan of Renuka Division).

Quercus leucotrichophora and the systematic survey was carried out in each Periodic Block, in each sampling unit (having 3 recording units each) were laid out for regeneration study and it was carried out in a square plot of size 2 m × 2 m by recording the number of seedlings (<0.5 m) and sapling (0.5-2 m) of tree species.

The primary goal of a regeneration survey is to determine whether or not adequate regeneration persists in the forest area. The number of established plants in a unit area was used to analyse regeneration adequacy. Chacko (1965) stated that the desired number of established plants per hectare is 2500, and the quadrate was considered fully stocked when it contained one established plant. The observations that follow were made for each quadrate to provide a comprehensive assessment of the status of regeneration.

Recruits, un-established, established and per cent regeneration

The total number of recruits (r):–It is defined as current year seedlings grown in the sample plot.

The number of un-established regeneration (u):– The seedling other than recruits, which has notbeen established by not reaching an established height of 2 m. Four un-established plants were considered equivalent to one established plant.

The number of established regeneration (e):– The seedlings which have attained above 2 m height.

The recruits, un-established and established regeneration were computed using formulae below as (Chacko 1965):

$$\text{Recruits (r)/ha} = \frac{2500 \times \text{total number of recruits}}{\text{Total number of quadrates studied}}$$

$$\text{Un-established regeneration (u)/ha} = \frac{2500 \times \text{total number of un-established plants in sampling units}}{\text{Total number of recording units}}$$

$$\text{Un-established regeneration (u)/ha} = \frac{2500 \times \text{total number of established plants in sampling units}}{\text{Total number of recording units}}$$

$$\text{Established regeneration (e)/ha} = \frac{2500 \times \text{total number of established plants in sampling units}}{\text{Total number of recording units}}$$

$$\text{Weighted average height (cm)} = \frac{\text{Total ht. of un-established regeneration} + (\text{Number of established plants} \times \text{establishment ht.})}{\text{Total un-established plants} + \text{Total established plants}}$$

Based on the above estimates following indices were calculated (Chacko 1965):

$$\text{Established index } (I_1) = \frac{\text{Weight average height}}{\text{Established height}}$$

$$\text{Stocking Index } (I_2) = \frac{1}{250} \times \frac{\text{Un-established regeneration}}{4} + \text{Established regeneration}$$

$$\text{Regeneration success (\%)} = \text{Stocking Index } (I_2) \times 100$$

$$\text{Established stocking percent} = 100\ (I_1 \times I_2)$$

RESULTS AND DISCUSSION

The present investigation on natural regeneration status of Ban Oak was carried out for different regeneration variables such as recruits, un-established, established and regeneration success in Quercus leucotricophora forest in Shillai, Nohra and Sangrah Forest ranges of Renuka Forest Division of Himachal Pradesh. The results on various regeneration variables are presented in Tables 1 - 2 and discussed below:

Natural regeneration studies of Shillai Forest Range

The inquisition of data presented in Table 1 evinced that Shillai range comprised of 3 tree species viz., *Pinus roxburghii, Pinus wallichiana* and *Quercus leucotricophora* as the prominent species, of which 3 species were found at Chaili (1800-2100 m). The regeneration success tended to decline with increase in altitudinal gradient as Shri Kiari (A_1) (77.78 %) > Bhatnaul (A_2) (69.44 %) > Chaili (A_3) (52.78 %). Maximum (77.78 %) regeneration was recorded at lower altitudinal gradient i.e., A_1, while minimum (52.78 %) regeneration was recorded at higher altitudinal gradient (1800-2100 m) i.e., A_3.

Established stocking per cent ranged from 9.95-21.56 % revealed a decreasing trend from A_1 (21.56 %) to A_2 (15.08 %) to A_3 (9.95 %). Established index was seen in an increasing trend from A_1 (0.19) to A_2

Table 1. Regeneration status of different tree species along altitudinal gradient in Nohra range of Renuka Forest Division, HP.

Shillaai							
Altitudes	R/ha	Un/ha	E / ha	Est Ind	SI	ESP (%)	Reg Suc (%)
A_1 (1200-1500 m)	2777.78	3333.33	1111.11	0.19	0.78	21.56	77.78
A_2 (1500-1800 m)	2500.00	3611.11	833.33	0.22	0.69	15.08	69.44
A_3 (1800-2100 m)	1944.44	3055.56	555.56	0.15	0.53	9.95	52.78
Nohra							
Altitudes	R/ha	Un/ha	E / ha	Est. Ind	SI	ESP (%)	Reg. Suc. (%)
A_1 (1200-1500 m)	2305.56	3111.11	888.89	0.25	0.67	16.69	66.67
A_2 (1500-1800 m)	1888.89	3416.67	527.78	0.12	0.55	8.61	55.28
A_3 (1800-2100 m)	1694.44	3055.56	361.11	0.11	0.45	6.58	45.00
Sangrah							
Altitudes	R/ha	Un/ha	E / ha	Est. Ind	SI	ESP (%)	Reg. Suc. (%)
A_1 (1200-1500m)	2694.44	3888.89	805.56	0.45	0.71	14.42	71.11
A_2 (1500-1800m)	2222.22	3611.11	694.44	0.44	0.64	12.54	63.89
A_3 (1800-2100m)	1638.89	2777.78	611.11	0.45	0.52	11.34	52.22

(0.22) and then decreased to A_3 (0.15). Maximum established individuals (1111.11 N/ha) were recorded at lower altitude A_1, while the minimum established individuals (555.56 N/ha) were recorded at upper altitudinal gradient A_3. The established individuals have also shown a decreasing trend with an increasing altitude.

Natural regeneration studies of Nohra forest range

In ban oak forest community of Nohra forest range, beside *Quercus leucotrichophora* other tree species recorded were *Cedrus deodara* and *Pinus roxburghii* that accounted for a total of 3 tree species of which 2 tree species were found in Chokar and Boghdhar respectively.

It is evident from Table 1 that Nohra forest range showed a decreasing trend of regeneration success with an increasing altitudinal gradient: Chokar (A_1) (66.67 %) > Boghdhar (A_2) (55.28 %) > Shilli (A_3) (45.00 %). Similarly, established stocking per cent followed a decreasing trend with an increasing altitudinal gradient as: A_1 (16.69 %) > A_2 (8.61 %) > A3 (6.58 %) in Nohra forest range. The established regeneration in Ban Oak forest in Nohra was 888.89 N/ha at A_1 and decreased in A_2 (527.78 N/ha) and A_3 (361.11 N/ha). Maximum un-established was found at middle altitude A_2 and established regeneration, establishment index, stocking index, establishment stocking per cent and regeneration percent in Ban Oak forest at lower altitudinal gradient i.e., A_1 and it is attributed to adequate number of seed bearers, site condition, comparative less thickness of organic matter and good soil properties in Nohra forest Range.

Natural regeneration studies of sangrah forest range

A scrutiny of data presented in Table 1 revealed that Sangrah forest range vegetation comprised of 3 tree species viz., *Rododendron arboreum, Pinus wallichaina* and *Quercus leucotrichophora* as the prominent species, of which 2 species (*Pinus wallichaina* and *Quercus leucotrichophora*) were found at Raicha and Sainjghat each and all the 3 species were found at Sundarghat. The regeneration success at Raicha and Sainjghat altitudinal gradient was relatively higher than Sundarghat altitudinal gradient.

Maximum regeneration success was found at Raicha (A_1) (71.11 %) to Sainjghat (A_2) (63.89 %) and minimum was found at Sundarghat (A_3) (52.22 %) altitudinal gradient. Established stocking percent was noted decreasing from A_1 (14.42 %) to A_2 (12.54 %) to A_3 (11.34 %). Un-established individuals decreased along increasing altitudinal gradient as well as, established individuals were found decreasing along increasing altitudinal gradient.

The appraisal of data presented in Table 2 shows mean regeneration status of Ban Oak in Renuka forest division. Maximum (71.85 %) regeneration was recorded at lower altitude i.e., A_1 greater than A_2 and A_3 altitudinal gradient.

The capacity of any species to regenerate is an essential aspect in determining its ability to create offspring and is influenced by a variety of circumstances. The natural regeneration results are evaluated and compared to the literature to better understand the regeneration status of *Quercus leucotrichophora* along an altitudinal gradient in the specified forest region. To evaluate regeneration status, Chacko's methodology, 1965 was used.

The established index, stocking index, established stocking percent, and regeneration percent

Table 2. Mean regeneration status of *Quercus leucotrichophora* (altitudinal gradient wise) in Renuka Forest Division.

Altitudes	R/ha	Un/ha	E / ha	Est Ind	SI	ESP %	Reg Suc %
A_1 (1200-1500m)	2592.59	3444.44	687.00	0.22	0.72	17.56	71.85
A_2 (1500-1800m)	2666.67	3546.30	685.19	0.18	0.63	12.08	62.87
A_3 (1800-2100m)	1759.26	2962.96	509.26	0.14	0.50	9.29	50.00
Mean	**2339.51**	**3317.90**	**627.15**	**0.18**	**0.62**	**12.98**	**61.57**

were found to decrease from lower to higher altitudinal gradient, indicating that seedlings at the higher altitudinal gradient germinate in high density but end up dying due to un-favorable conditions. At the higher altitudinal gradient of poor regeneration, seed germination may be hampered by a lack of suitable good seed bearers, slope, animal and human interference. The variation in seedling density across forests and/or species along the altitudinal gradient could be attributed to climatic variations, that would limit several species' dispersal through seedling germination and establishment (Vera 1997). Ban Oak is being lopped aggressively for fodder and grazing. The low figure of un-established plants in Ban Oak woods may be attributable to tree looping for fodder and fuelwood. Rangel and Vargas (2000) unearthed that Ban Oak species monopolised the canopy but not the understory. Shrestha (2003) revealed the loss of seedlings and tiny trees in the Himalayan area before they reach the canopy.

In general, inadequate regeneration is a key issue in mountain forests (Krauchi *et al*. 2000). Seeds serve an important part in the natural regeneration of tree species. The most crucial need for natural regeneration from seed is that the tree in the region or near vicinity produces sufficient numbers of viable seed (Deiller *et al.* 2003). Acorn yield varies greatly from year to year, and seed loss due to insects such as weevil assault, birds, and animal predation can be significant. Oak seeds are heavily predated by a number of animals and insects, spontaneous regeneration may be ineffective unless they are well managed (Harmer 1994). *Q. leucotrichophora* produces a wide range of seed crops. Minimum regeneration was recorded at higher altitudinal gradient (1800-2100 m) i.e., A_3 because of lack of sufficient regeneration in mountain forests and the results draw support from the findings, reported by Krauchi *et al.* (2000).

Dense canopy in forests such as mixed *Quercus leucotrichophora* forests, mixed *Quercus floribunda* forests and mixed *Rhododendron arboreum* forests contained lower densities of seedlings at various altitudinal gradients (Tiwari *et al.* 2018).

Insufficient viable seeds due to insect and animal predation, unfavorable micro-sites, and domestic livestock overgrazing are all causes of regeneration failure. Inconsistent seed production, defoliation, acorn predation, and fire hazards frequency are all factors contributing to the decline of oak forests. The highest number of un-established oak seedlings in the Ban oak forest may be likened to excessive looping of trees for fodder, fuel, and grazing, which causes oak seedlings to remain un-established, as reported by Aldrich *et al.* 2005 for the old-growth forest of India (Ammer 1996) for mixed forest areas in the Bavarian Alps. Dobrowolska (2008) investigated the influence of stand density on oak regeneration in a flood plain forest in lower Silesia, Poland (Russia). Water deficiency and trash buildup have also been observed to impede seeding survival by Seiwa and Kikuzawa (1996) and Seiwa (1997).

An inhabitant with an adequate number of seedlings and saplings of the species in a forest exhibits excellent regeneration, whereas a population with an insufficient number of seedlings and saplings of the species in a forest exhibits poor rejuvenation (Tripathi and Khan 2007). According to Rangel and Vargas (2000), ban oak species monopolised the canopy while not the understory. Ammer (1996) discovered consistent patterns while studying spontaneous regeneration of mixed forest areas in the Bavarian Alps. Cattle, goats, and sheep, according to Shrestha and Paudel (1996), graze the tiny saplings of oak trees in Nepal's oak woodlands. These factors may have reduced sapling quantity; in these woods, oak sapling damage through monkeys, acorn worms, other birds, and rodents is more prevalent (Rawat and Singh 1988).

Reduced illumination intensity on the forest floor caused by high overhead canopy, according to Barik *et al.* (1992). Despite the fact that the response of tree seedlings to changing climate has garnered slight consideration. Variations in snow pattern and temperature, as discovered by Nautiyal *et al.* (2004) and Chaturvedi *et al.* (2007), alter plant distribution and phenotypic expression. As reported by Shakith *et al.* 2023, soil edaphic parameters along with altitudinal gradient yield a net impact on intricate harmony between soil conditions and growth characteristics and natural generation of Terminalia chebula in

Garhwal Himalaya.

CONCLUSION

The regeneration success of *Quercus leucotrichophora* ranged from 50.00 to 77.78 per cent in Renuka Forest Division. Maximum (72.22 %) regeneration success was recorded at A_1 (1200-1500 m) and minimum regeneration success 53.70 % was recorded at A_3 (1800-2100 m) altitudinal gradient. Establishment index, stocking index, establishment stocking percent and regeneration percent was found decreasing from lower to higher altitudinal gradient which shows that seedlings at higher altitudinal gradient may germinate in high density but due to unfavorable conditions at higher altitudinal gradient, seedlings face mortality. As a result, their protection and sustainable usage in the future are essential to reduce the effects of climate change, as well as the biological and environmental stability of sensitive ecosystems in North-western Himalayan ecosystem. Ban Oak Forest also plays a very important role for protection and nutrient enrichment in order to improve forest ecosystem services. Local communities' active co-operation is required for the sustainability of these valuable species. Long-term biodiversity goals can be met by enhancing their livability and delivering them with sustainability benefits. To enhance our knowledge of ecosystem functions and processes, in addition to develop a holistic characterization of the landscape, we need both intensive analyses on small areas and evaluations on much larger areas.

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